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REACTIONS OF GOLD WITH INDIUM AND AN INDIUM SOLDER*

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Reactions of Au with In are well known, and Au reacts preferrentially with In in a 37.5/37.5/25 weight % Pb/Sn/In solder (hereafter "solder"). This solder has been used for bridgewires in several weapons now in stockpile. Reaction rate data are needed to help determine stockpile life, but existing data show variations greater than a factor of 5 at extended times.[1]

Powell and Braun[2] found Au_4In, Au_9In_4, AuIn, and $AuIn_2$ for the Au-In system, with the last being most prominent, and the first not always present. Braun and Rhinehammer[3] reported only $AuIn_2$ for a Au-solder system. Yost, Ganyard, and Karnowsky[4] found Pb dispersed in the boundaries of $AuIn_2$ crystals in a Au-Pb/In system. Their analyses of reaction layer growth kinetics could fit both exponential and linear growth laws. Some data suggest the controlling step changes after extended times.[1,4]

We studied Au wires cast in In or solder. Spools containing 0.82, 0.25, and 0.038 mm (0.032, 0.010, and 0.0015 inch) Au wires were cast in In or solder at 185°C for 1 minute. These slugs were treated at 100° or 120°C, and samples sliced off at intervals. We measured the reaction layer thickness in polished samples. "Zero time" reaction layers due to the casting process were all < 0.1 μm thick. Diamond pyramid hardness values were found for some reaction layers of sufficient size.

Selected samples were studied by scanning electron microscope. Phase compositions were determined by microprobe analyses using wavelength dispersive spectroscopy (WDS) or energy dispersive spectroscopy (EDS).

RESULTS AND DISCUSSION

Reaction layer thicknesses are shown as a function of time at 100°C in Figure 1 for the Au wires in In. Individual coatings had uneven thicknesses,

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and the data show considerable scatter. Still, the trend of the data would have a slope close to 1, suggesting a linear growth law. For times of several hundred hours or more, geometric effects were apparent: the smallest wire had the slowest continuing growth, which is expected as diffusion begins to be important in the process. After 1830 hours most of the 0.038 mm (0.0015 inch) Au wires had completely reacted with In.

Corresponding data at 100° and 120°C for Au wires in solder is shown in Figure 2. Again, there is considerable scatter in the data, and we see similar geometric effects at longer times according to the wire size. Reaction layer thicknesses in solder are about one-half to one-third of those in In at the longer times, certainly due to the reduced concentration of In in solder. We have only limited data at 120°C to date.

A 0.038 mm (0.0015 inch) Au wire in In is shown in Figure 3 after 66 hours at 120°C. When reaction layers are this thick, we see a characteristic ring of pores in the reaction product as shown. Vickers microhardness tests give different values on either side of the pores, indicating different reaction products. Combined EDS microprobe and microhardness data for this sample are shown in Figure 4. Only the outermost layer was positively identified, being $AuIn_2$. Microhardness ranged from 79 to 102 kg/mm^2; Powell and Braun[2] reported 77 kg/mm^2 for $AuIn_2$.

Phases in reaction layers formed at 100°C for 702 hours in both In and solder samples were determined using both EDS and WDS microprobe analyses. Here the phases on individual wires within each casting and even different areas on a single wire were not all alike. Within the Au-In sample we found:

Wire 1: Au_9In_4 - $AuIn_2$

Wire 2: $AuIn$ - $AuIn_2$

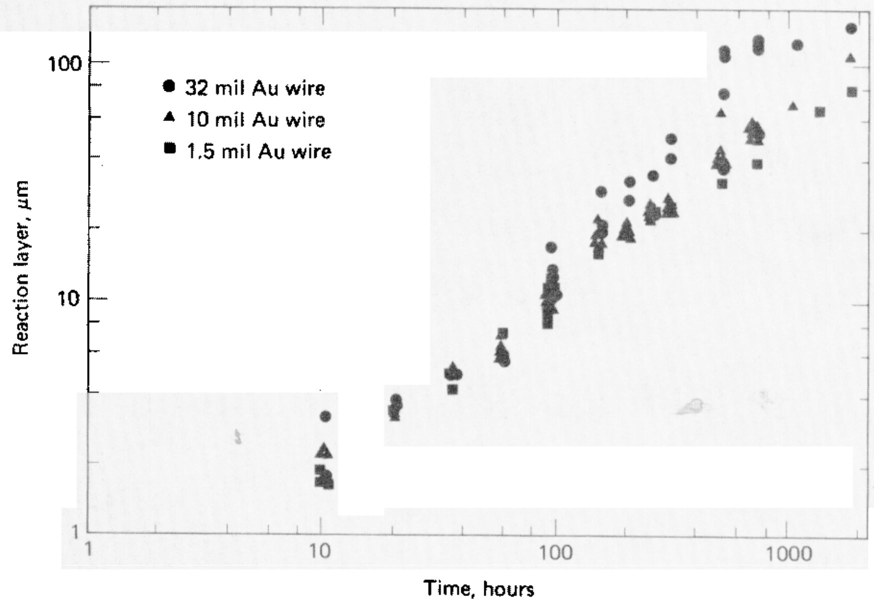
Wire 3: $\left\{ \begin{array}{l} AuIn - AuIn_2 \\ AuIn_2 \end{array} \right.$

Within the Au-solder sample we found:

$\left. \begin{array}{l} \text{Wire 1:} \\ \text{Wire 2:} \\ \text{Wire 3:} \end{array} \right\} AuIn_2$

Wire 4: $AuIn$ - $AuIn_2$

Figure 1. Au-In reaction layer thickness after treatment at 100°C.



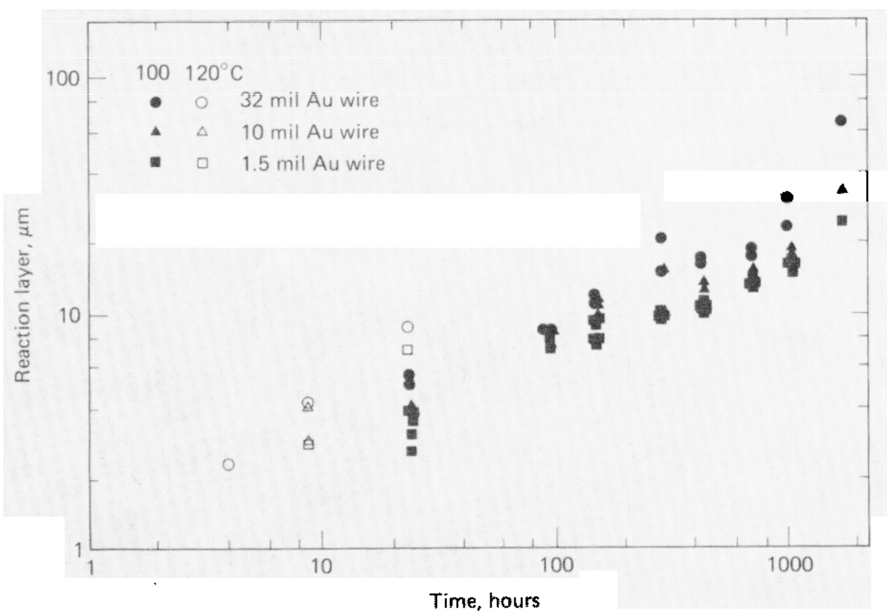
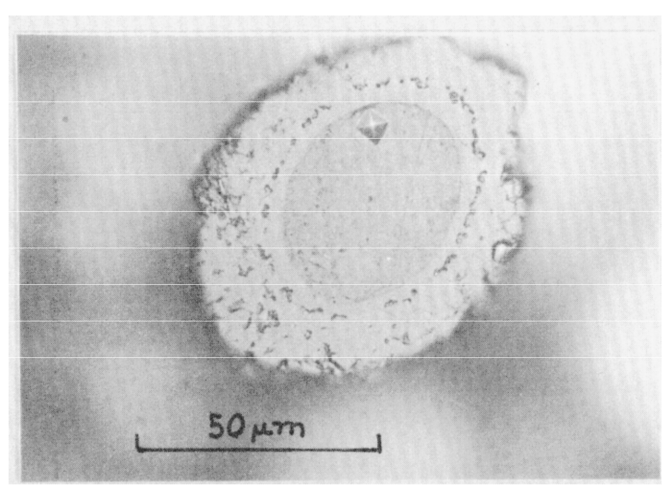


Figure 2. Au-solder reaction layer thicknesses after treatment at 100° and 120°C. Solder is 37.5 Pb/37.5 Sn/25 In.

Figure 3. In reaction around a 1.5 mil Au wire after 66 hours at 120°C.



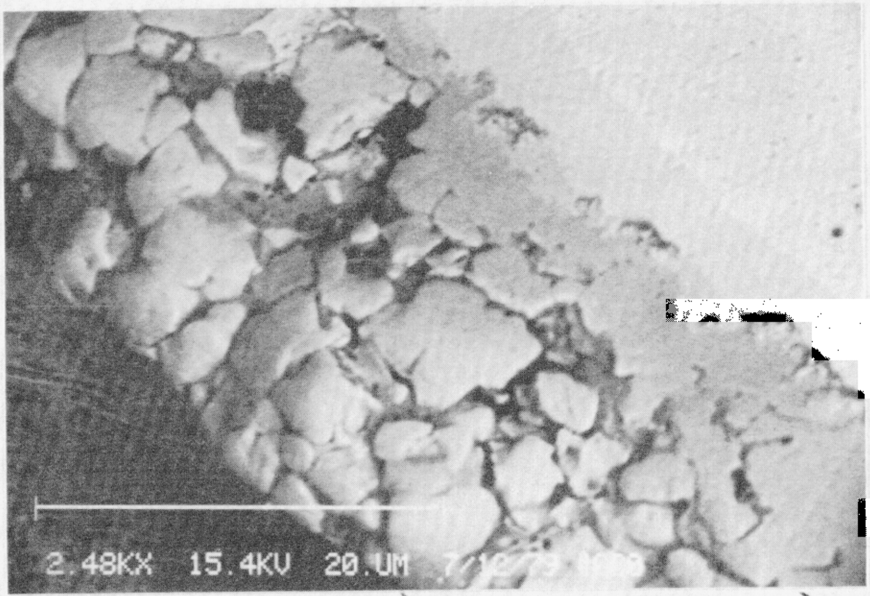


Figure 4. Enlarged section of reaction layer shown in Figure 3.

We can not readily explain the variation in phases present on different wires in the respective castings. However, these differences along with variations in overall reaction layer thicknesses on a given wire may explain the wide variations in field data.

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